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to determine its exact course. My paper, "Senesence and Rejuvenation," affords evidence of new facts proven by these experiments. I believe I have thus won the right to oppose my view to the pure speculations of Weismann.

(*To be continued.*)

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## LOST CHARACTERISTICS.

By Alpheus Hyatt.

Dr. Minot having noticed, in the translation of his article "On Heredity and Rejuvenation," an accidental omission of quotation of work done by paleontologists on the loss of characteristics in the development of animals, has most courteously asked me to follow his essay by an article dealing with this question. I gladly avail myself of this opportunity on account of the advantages offered where similar subjects can be consecutively treated from different points of view, and because Dr. Minot's article, on account of his great and deserved reputation in embryology, will reach the students of existing biological phenomena, and perhaps induce some of them to read a connected publication.

The loss of characteristics is not so readily observed by a student of the biology of existing animals or neobiologist, as by the paleobiologist or student of fossils, because the latter necessarily deals with series of forms often persisting through long periods of time, and is led, especially if he follow more recent methods of research, to study these in great detail. The observer of these remains is not, as is falsely imagined, limited to fragments, but can and does work out of the hard matrix the external skeletons or shells even of embryos, and can, in the corals, brachiopoda, mollusca, echinodermata and even in protozoa, follow the entire life history of these parts in the individual. He has also the further advantage of availing himself of the knowledge amassed by the neobiologist and neoembryologist, the works of Cope, Beecher, Schuchert, Gurley,

Jackson and others, written in the last thirty years in this country and in Europe. The new school of Paleobiology also insists upon the close study of series of forms and rejects the methods usually pursued by the neoembryologist, who, as a rule, selects his objects of study and pursues his comparisons upon the old basis of comparative anatomy and with but little regard to the serial connections of forms. The importance of studying the seriality in structure of the members of the same group, those gradations, which lead from one variety to another, one species to another, one genus to another, until they may end in highly differentiated and often degraded offshoots, with as strange and unique developments as they have adult characters, seems not, as yet, to have attracted the attention of the students of development among recent animals as it has that of paleobiologists. The prevalent modes of study of living types has consequently led to noticing the phenomena of omission of hereditary characters only in an isolated way, and from the time of Balfour's "Comparative Embryology" these omissions occurring in the embryo have been named abbreviations, shortenings and omissions of development, and various attempts have been made to explain them upon more or less general grounds of inference. Prof. Cope and the writer and some other authors have been for a number of years publishing observations upon this class of phenomena under the title of the law of acceleration, asserting that in following out the history of series in time, or of existing series in structure, there was observable a constant tendency in the successive members (species, genera, etc.) of the same natural group to inherit the characters of their ancestors at earlier stages than those in which they appeared in these ancestors. That as a corollary of this tendency, the terminal forms eventually skipped or omitted certain ancestral characteristics, which were present in the young of the preceding or normal forms of the same series. and also in the adult stages of development of more remote ancestors of the same genetic stock or series. This law has since been independently rediscovered by several other naturalists, notably Würtemburger in Germany, and Buckman in England. The writer has lately christened this as the law of

Tachygenesis[1] in allusion to the general character of the phenomena.

In a late paper,[2] the writer reviewed Prof. Cope's and Haeckel's views of this law, and contrasted them with his own, and it seems advisable to give these remarks again in this connection.

Professor Cope has given the fullest explanation of this law, but has joined it with retardation. Thus, from his point of view, if I rightly understand him, inexact parallelism in development or failure to reproduce any hereditary characteristics is due to a tendency which appears in organisms and works in parallel lines with acceleration, the law being in his conception of a double nature. Thus he says, on page 142 of his "Origin of the Fittest," "The acceleration in the assumption of a character progressing more rapidly than the same in another character, must soon produce, in a type whose stages were once the exact parallel of a permanent lower form, the condition of inexact parallelism. As all the more comprehensive groups present this relation to each other, we are compelled to believe that acceleration has been the principle of their successive evolution during the long ages of geologic time. Each type has, however, its day of supremacy and perfection of organism, and a retrogression in these respects has succeeded. This has, no doubt, followed a law the reverse of acceleration, which has been called retardation. By the increasing slowness of the growth of the individuals of a genus, and later and later assumption of the characters of the latter, they would be successively lost. To what power shall we ascribe this acceleration by which the first beginnings of structure have accumulated to themselves through the long geologic ages, complication and power, till from the germ that was scarcely born into a sand lance, a human being climbed the complete scale, and stood easily the chief of the whole." And again, on page 182 of the same work: "Acceleration signifies addition to the number of those repetitions during the period

[1] "Phylogeny of an Acquired Characteristic." Proc. Am. Phil. Soc. Philadelphia, XXXII, No. 143.

[2] "Bioplastology and the Related Branches of Biologic Research." Proc. Bost. Soc. Nat. Hist., XXVI, p. 77–81.

preceding maturity, as compared with the preceding generation, and retardation signifies a reduction of the numbers of such repetitions during the same time." Thus, from Cope's point of view, tachygenesis is the law of progression, and retardation is the law of retrogression, and they are both essential parts of his law of acceleration and retardation.

Haeckel alludes in general terms to the law of abbreviated development in his "Morphologie der organismen," and in his "Anthropogenie," published in 1874, substantially agrees with Cope in his view of the law and uses the term "palingenesis" for the exact repetition of characteristics which occurs in the earlier and simpler forms of a phylum and "coenogenesis" for the abbreviated or highly accelerated cases of inexact parellism of the young of more complex forms with their ancestors. There is, however, an objection to this mode of using the last term which I mentioned also in writing the paper quoted.[3]

[3] During the writing of this paper I took from Cope the statement made above, although unable to find any verification of it in Haeckel's Anthropogenie (1st and 2d editions both dated 1874), but, since the above was in press, I obtained a copy of the 4th edition (1891) and the reading of this has caused me to entirely alter my opinion with regard to Haeckel's opinions. He certainly had at that time, 1891, what seems to me erroneous and inadequate view of the nature and action of the laws of tachygenesis and gave it too limited application. He also used the terms, palingenesis and cenogenesis differently from the way in which Cope and others have used them in this country.

Haeckel states (Anthropogenie, 4th edition, Leipzig, p. 9, 1891) that "Palingenetische Processe oder keimesgeschichtliche Wiederholungen nennen wir alle jene Erscheinungen in der individuellen Entwickelungsgeschichte, welche durch die conservative Vererbung getreu von Generation zu Generation übertragen worden sind und welche demnach einen unmittelbared Rückschluss auf entsprechende Vorgänge in der stammesgeschichte der entwickelten Vorfahren gestatten. Cenogenetische Processe hingegen oder keimesgeschichtllche *Störungen* nennen wir alle jene vorgänge in der keimesgeschichte, *whelche* nicht auf solche vererbung von uralten stammformen zurüchführbar, vielmehr *erst spater durch Anpassung der Keime oder der Jugendform* an bestimme Bedingungen der Keimesentwickelung hinzugekomen sind. Diese ontogenetischen Erscheinungen *sind fremde zuthaten* welche *durchaus keinen unmittelbaren Schluss anf entsprechende Vorgänge in der stammesgeschichte* der Ahnenreihe erlauben, vielmehr die Erkenntniss der letzteren geradezu fälschen und verdecken."

So far as one can get at Haeckel's oplnions from such expressions as the above it is obvious that he views shortened or abbreviated development in a very distinct light from that to which I am accustomed. He speaks of it as due to the introduction of "fremde zuthaten" as "Cenogenetische oder Störungsgeschichte"

and further to make his meaning clearer, on page 11 he divides cenogenetic phenomena into " Ortsverschiebungen oder Heterotopien," and, on page 12, "Zeitverschiebungen oder Heterochronien." Organs or parts may be developed heterotopically, that is, out of place or in a different part of the body from that in which they originated in the ancestors; or heterochronically, that is earlier in time during the life of the individual than that in which they originated, and he also speaks of the latter as " ontogenetische Acceleration," using exactly the adjective applied in this country many years beforehand, but that fact does not seem to have been considered worthy of his attention. Haeckel then proceeds to add: " Das umgekehrte gilt von der verspäteten Ausbildung des Darmcanals, der Leibeshöhle, der Geschlechtsorgane. Hier liegt offenbar eine Verzögerung oder Verspätung, eine *ontogenetische Retardation.*" This is probably what Cope alludes to in his quotation of Haeckel, and certainly this is a restatement of Cope's law of retardation with, however, the ommission of any reference to the original discoverer. It will be gathered from the text above that I view acceleration firstly, as a normal mode of action or tendency of heredity acting upon all characters that are genetic, or, in other words, derived from ancestral sources; secondly, that a ctetic, or, in other words, a newly acquired character must become genetic before it becomes subject to the law of tachygenesis. Haeckel has evidently confused ctetic characters like those of the so called ovum of Taenia, the Pluteus of Echinoderms and the grub, maggot, caterpillars of insects, which have caused the young to deviate more or less from the normal line of development, as determined by the more generalized development of allied types of the same divisions of the animal kingdom, with the normal characters that are inherited at an early stage in the ontogeny and considers them all as heterochronic. It is very obvious that they are quite distinct and that, while the ctetic characters may have been larval or even possibly embryonic in origin, and may not have affected perceptibly the adult stage at any time in the phylogeny of the group, they are, nevertheless, subject to the law of acceleration and do affect the earliest stages as has been shown in Hyatt's and Arm's book on Insecta. Such characteristics do, of course, contradict the record, if we consider that the record ought have been made by nature according to anthropomorphic standards, and in such misleading phraseology they are falsifications of the ontogenetic recapitulation of the phylogeny. In a proper nomenclature, framed with due regard to natural standards, such expressions are inadmissable. There is absolutely no evidence that characteristics repeated in the younger stages of successive species and types owe their likeness to ancestral characters to other causes than heredity. This likeness may be interfered with or temporarily destroyed by extraordinary changes of habit, as among the larvae of some insecta and the forms alluded to above, or among parasites in different degrees, but the obvious gradations of structures in many of these series show that hereditary tendencies are not easily changed in this way. There are comparatively very few forms having doubtful affinities even among the parasites. It is also evident that the novel larval characters originating in the young in their turn speedily become hereditary and are incorporated in the phylogeny and recapitulated in the ontogeny.

It may be seen from this that in dividing tachygenesis into palingenesis and cenogenesis the writer has followed Cope rather than Haeckel, and there is a seri-

Either through want of acquaintance with good examples of retardation or because of a different point of view, I have not been able to see any duplex action in the law of acceleration. To me it is the same law of quicker inheritance which is acting all the time in the phylum at the beginning, middle, and end of its history, as will be seen by the explanation given above. In Insecta[4] I have tried to apply it to the explanation of the peculiar larval forms of those animals which often present retrogression through suppression of ancestral characters in the young, although their adults are perfectly normal and perhaps progressive. Consequently, palingenesis and coengenesis are, from my point of view, simply different forms of tachygenesis, and there is no boundary or distinction between them. In other words, retardation or retrogression occurs because of the direct action of tachygenesis upon more suitable and more recently acquired characteristics which are driven back upon and may directly replace certain of the ancestral characters causing them to disappear from ontogenetic development.[5]

ous objection to the use of cenogenesis at all, since it is from *Κενός* meaning strange, and was first applied by Haeckel in such a way that both by his statements, and the derivation, it ought to be confined to types like larvae of the Echinodemata Insect, etc., and parasites in which acquired characters do interfere with the ontogenic recapitulation for a certain time. Normal types, in which tachygenesis occur in a marked way might be called tachygenetic. Palingenesis and palingenetic might be confined to generalized forms in which the ontogeny was a more or less prolonged recapitulation of the phylogeny, and coenogenesis would thus be properly confined to its original field wherever ctetic characters were introduced. This would avoid the need of using a new term.

[4] Guides for Science Teaching, Boston Soc. Nat. Hist., No. 8.

[5] Specialization by reduction of parts is evidently included under the head of retardation by Cope; thus in Origin of the Fittest, p. 353, he says that "change of structure during growth is accomplished either by addition or parts (acceleration) or by subtraction of parts (retardation)." So far as my experience goes in the major number of cases, the parts of characters that are undergoing reduction disappear according to the law of tachygenesis. They reappear in the ontogeny at earlier and earlier stages, or exhibit this tendency in the same way as characters of the progressive class, but their development is not so complete as in ancestral forms. In this sense they can be regarded as retarded or thrown back in their development. There is, however, another way of formulating the expression for this. Instead of regarding this disappearance by retrogressive gradations as due to a tendency opposed to acceleration, is it not a tendency of the same

The law of tachygenesis as defined by the writer acts upon all characteristics and tendencies alike, and is manifested in genetically connected phyla by an increasing tendency to conconcentrate the characteristics of lower, simpler, or earlier occurring, genetically connected forms in the younger stages of the higher, more complicated or more specialized, or more degraded, or later occurring forms of every grade, whether the characteristics arise in adults or in the younger stages of growth. Since my first publication in 1866, the law has become clearer to me, but I have made no fundamental change in the conception. The application of the law to degenerative characteristics appears to me to explain why there are degenerative forms in the phylum which are indicated by the senile stages of the individual.

The degenerative changes of the senile period may, and practically in all cases do, tend to the loss of characteristics of the adult period and consequently in extreme cases bring about not only the loss of a large proportion of progressive characteristics, but loss in actual bulk of the body as compared with adults, as has been stated above. This is usually regarded as due to the failure of the digestive organs or defective nutrition, and this may be true in many examples; but, on the other hand, it often begins in individuals long before there is any perceptible diminution in size, and may occur in dwarfs and in some degenerate species in the early stages, and finally in series of species according to the law of tachygenesis, so that

kind? That is to say, do not the parts and characters show a tendency to disappear earlier and earlier, and are they not, in most cases, at the time of disappearance, present also in earlier stages of growth than that in which they originated in ancestral forms?

Is not the case of the wisdom teeth exceptional? The frequently extremely late external appearance of these is not accompanied by a later origin of their rudiments in the jaw. Although they may not appear in many cases above the gum until a person is past fifty, is not this retardation in becoming externally visible due primarily to the fact that they are deficient in growth power (tending to disappear from disuse, etc.), and secondarily to their internal position. When they cease to be able to break through the gum, will they not still continue to develop at the same stage as the other teeth, and will not their rudiments be likely tobe present at this early stage long after they have ceased developing into perfect teeth?

one is led to believe that the tendency to the earlier inheritence of degenerative modifications producing retrogression is inheritable like the tendency to the earlier inheritance of additional or novel characteristics producing progression. Thus, this law applied to progressive or retrogressive groups explains the mode in which their progression or retrogression is accomplished so far as the action of the laws of genesiology (science of heredity) are concerned.

In the same essay on Bioplastology, the writer reviewed Dr. Minot's law of growth, and in this and in his Phylogeny, quoted above, used it to throw light upon one of the most difficult problems of evolution.

It is a general law of unique importance, as readily observable in the growth of skeletons and shells of all kinds, and therefore as obvious in fossils as in the famous guinea pigs studied by Dr. Minot. This law enabled the writer to get what seemed to him a clearer view of the action of tachygenesis. See Bioplastology (p. 76).

Minot's researches enable one to see clearly that the reduction of parts or characteristics which takes place through the action of the law known as the law of acceleration in development (often also descriptively mentioned as abbreviated or concentrated development) cannot be considered as due to growth.

"It seems probable from my own researches published in various communications, but more especially in the 'Genesis of the Arietidae,'[6] that the action in this case is *a mechanical replacement of the earlier and less useful ancestral characteristics and even parts by those that have arisen later in the history of the group.* We can fully understand the phenomena of acceleration in development only when we begin by assuming that the characteristics last introduced in the history of any type were more suitable to the new conditions of life on the horizon of occurrence of the species than those which characterized the same stock when living on preceding horizons or in less specialized habitats. These new characters would necessarily, on

[6] Smithsonian Contributions to Knowledge, v. 26, p. 40–48, 1889; also, Mus. Comp. Zool., v. 16, 1889.

account of their greater usefulness and superior adaptability, ultimately interfere with the development of the less useful ancestral stages and thus tend to replace them. The necessary corollary of this process would be tachygenesis or earlier appearrance of the ancestral stages in direct proportion to the number of new characteristics successively introduced into the direct line of modification during the evolution of a group.

If this be true, it can hardly be assumed that the loss of characteristics and parts taking place in this way is directly due to growth force. If growth has anything to do with these phenomena, it must act indirectly, and, as in the repetition of other similarities and parallelisms, under the controlling guiddance of heredity.

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## VARIATION AFTER BIRTH.

By L. H. Bailey.

At the present time, our attention is directed to differences or variations which are born with the individual. We are told that variation which is useful to the species is congenital, or born of the union—or the amalgamation in varying degrees—of parents which are unlike each other. From the variations which thus arise, natural selection chooses those which fit the conditions of life and destroys the remainder. That is, individuals are born unlike and unequal, and adaptation to environment is wholly the result of subsequent selection.

These are some of the practical conclusions of the NeoDarwinian philosophy. It seems to me that we are in danger of letting our speculations run away with us. Our philosophy should be tested now and then by direct observation and experiment, and thus be kept within the limits of probability. The writings of Darwin impress me in this quality more than in any other,—in the persistency and single-mindedness with which the author always goes to nature for his facts.